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Chapter Fifty-Two

PAVEMENT AND UNDERDRAIN DESIGN ELEMENTS

52-1.0 INTRODUCTION

This chapter provides guidelines for the design of pavements for the State and Local roadway systems. The pavement type selection and thickness is determined based on an economical analysis considering subgrade conditions, environmental conditions, pavement material properties, and traffic loadings. Recent advances in technology have enabled pavement designers to consider longer design lives while staying within the economic constraints of the system. Underdrains are specified for subgrade and / or pavement drainage purposes.

52-2.0 HISTORY

Indiana's pavements are generally constructed of either asphalt or portland cement concrete. Asphalt pavements are generally referred to as flexible pavements and are composed of a liquid binder in combination with coarse and fine aggregates. Flexible pavements are typically constructed using Hot Mix Asphalt. Portland Cement Concrete Pavements are generally referred to as rigid pavements. Aggregate pavements are constructed with compacted aggregate. The pavement structure is considered to be that part of the road that is placed on the finished subgrade and includes all paved surfaces including shoulders.

Surfaces used for roadways in Indiana in the past included bricks, aggregates, and Kentucky rock asphalt. Bricks were commonly placed on a sand base and are still often discovered under layers of old pavements. Aggregates were a common building material when roadways first were being built and can still be found on many county roadway systems in Indiana. Kentucky rock asphalt is a naturally occurring asphalt that has not been used in recent years but can be found within existing pavement structures when coring the roadway.

Underdrains have been utilized on Indiana’s roadways since the 1950s. Transverse underdrains were some of the first underdrains utilized. This type of underdrain was typically a drain tile or perforated pipe constructed perpendicular to the pavement and spaced longitudinally throughout the project. Beginning in the 1960s, longitudinal pipes were constructed along the edges of the pavement and outlet to the side ditches. Typically little or no maintenance was performed on the underdrain systems until a mid-1990 study showed that poor performance of the underdrain system was causing failures of pavement structures.

52-3.0 ABBREVIATIONS

AASHTO	American Association of State Highway Transportation Officials
CAB	Compacted Aggregate Base
ESAL	18 Kip (80 kN) Equivalent Single Axle Load
FWD	Falling Weight Deflectometer
HMA	Hot Mix Asphalt
INDOT	Indiana Department of Transportation
LCCA	Life Cycle Cost Analysis
LPA	Local Public Agency
PCCP	Portland Cement Concrete Pavement
PG Binder	Performance Graded Binder

52-4.0 PAVEMENT DEVELOPMENT PROCESS

Considerations for pavement design occur during the Engineer's Report and design phase. The pavement treatment is determined during the Engineer's Report phase and the type and thickness are determined during the design phase.

52-4.01 Scope

Projects such as Added Travel Lanes, Interchange Construction, Road Rehabilitation (3R/4R Projects), New Construction, or Rest Areas / Weigh Station Construction require that an Engineer's Report identify a preliminary pavement design prior to design being started. The preliminary pavement design describing the treatment and approximate thickness is to be recommended in the Engineer's Report.

The Materials and Tests Division's Pavement Design Section becomes involved with the decision making at the invitation of the Program Development Division or the Environment, Planning and Engineering Division's Engineering Assessment Section, or the appropriate district's development section. For LPA projects, the LPA's agent may submit a preliminary design for approval to the Pavement Design Section.

For district-developed projects, the Engineer's Report should be developed based on an analysis of Pavement Management System data. The Materials and Tests Division's Pavement Design Engineer will determine the pavement type and structure for roads having AADT greater than 5,000 or having Average Daily Truck Traffic (ADTT) greater than 500. If the AADT is less than

5,000 or the ADTT is less than 500, the District's project designer will determine the pavement type and structure.

52-4.02 Design

The Pavement Design Section prepares pavement designs at the request of the project designer for INDOT projects or approves pavement designs at the request of the LPA's agent for LPA projects. Pavement design requests are submitted on the appropriate forms for INDOT and LPA projects. The LPA's request should be prepared and signed by an Indiana Professional Engineer. Consideration for the use of underdrains in the pavement section is to be in accordance with Section 52-10.0.

52-5.0 PAVEMENT TYPES

The types of pavement used are aggregate, asphalt, portland cement concrete, or composite.

52-5.01 Aggregate Pavement

Aggregate pavements consist of a dense graded compacted aggregate placed on a prepared subgrade. The pavement is typically composed of compacted aggregate base size No. 53 or compacted aggregate base size No. 73.

52-5.02 Asphalt Pavement

New asphalt pavements typically consist of an HMA surface course, on an HMA intermediate course, on HMA base or compacted aggregate, directly on a prepared subgrade. Asphalt pavement overlays usually consist of a surface course on an intermediate course on the existing pavement or new base. HMA is a mixture of binder and aggregates. Drainage layers may be utilized in the intermediate and base mixtures. Typical sections for HMA pavements are included in Section 52-13.0.

52-5.02(01) HMA Surface

The surface course performs several functions for the pavement structure. Its major function is to reduce the amount of water from entering the pavement, to provide a friction course to ensure good friction properties throughout the design life, to provide a riding surface to provide a smooth ride, and to provide a structural layer to help carry the anticipated design traffic.

52-5.02(02) HMA Intermediate

The intermediate course also performs several functions for the pavement structure. Its major function is as a leveling course to help create a smooth pavement, and a structural course to help carry the anticipated design traffic.

52-5.02(03) HMA Base

The base course is designed as a structural layer to help carry the anticipated design traffic concurrent with its role in handling or keeping water out of the pavement system by isolating the subgrade. Base material is a dense graded, practically impermeable mixture.

52-5.02(04) Open Graded Drainage Layer

When open graded drainage layers are called for, mixtures such as QC/QA-HMA Intermediate OG 25.0 mm or OG 19.0 mm are used as a conduit to remove water entering the pavement system, and as structural layers to help carry the anticipated design traffic loads. When open graded mixtures are specified, underdrains shall be included.

52-5.02(05) Compacted Aggregate Base

Compacted aggregate base, when required, functions as a structural layer while economically increasing the pavement thickness to help protect the pavement from the effects of frost action.

52-5.03 Portland Cement Concrete Pavement

Plain jointed Portland Cement Concrete Pavement consists of concrete materials on a subbase and a prepared subgrade. PCCP is composed of portland cement, pozzolans, coarse and fine aggregates, water, and chemical admixtures.

Subbase is a granular layer placed under PCCP to minimize pumping of erodable subgrade material and to provide support for the pavement. Subbase may be classified as drainable or dense. A drainable subbase provides a conduit to remove water that enters the pavement system and should be used for all pavements where underdrains are required. A dense graded subbase provides for a stable-working platform together with support for the pavement without drainage layers.

1. Drainable Subbase A drainable subbase consists of an aggregate drainage layer over a compacted aggregate separation layer.

2. Dense Subbase. A dense subbase consists entirely of compacted aggregate.

52-5.04 Composite Pavements

Composite pavements consist of multiple pavement types, i.e., HMA over PCC Base, PCCP over asphalt or asphalt/PCC composite pavement, or HMA over compacted aggregate base. Composite pavements may be used in widening situations where the existing composite pavement is considered to be in generally satisfactory condition. The widened pavement will typically match the existing sections of the existing pavement. Composite pavements should be designed in accordance with Section 52-9.04.

52-6.0 PAVEMENT SURFACE DISTRESSES

The strengths and limitations of all pavement systems must be understood prior to designing a pavement. Common pavement weaknesses, distresses, and their causes and recommended treatments are listed below.

52-6.01 Aggregate Pavement

1. Dusting. Dusting is caused by the displacement of road fines by traffic causing a cloud of dust behind user vehicles. The recommended treatment for dusting is to use a dust palative.

2. Potholing. Potholing is caused by traffic displacing weakened areas of the unbound pavement. Insufficient structural strength, segregation in the aggregate surface, or soft subgrade conditions typically cause the weakened areas. The recommended treatment for isolated potholes is regrading the surface. However, the recommended treatment for numerous potholes in the pavement requires additional aggregate to be placed on the roadway prior to regrading.

3. Rutting. Rutting is caused by traffic displacing the unbound aggregate outside the wheel paths or to the sides of the road. The recommended treatment is to regrade the roadway to replace the displaced aggregate. In severe situations, the placement of additional aggregate may be required prior to regrading.

4. Washboarding. Washboarding or corrugations develop across the road perpendicular to the direction of traffic. There are three primary causes for washboarding: too-fast driving habits, lack of moisture, and poor quality aggregates. It is most prevalent under heavy loads or where traffic accelerates or decelerates. The recommended treatment for light washboarding is to correct it by regrading the roadway. The recommended treatment for moderate to severe washboarding is milling 25 to 50 mm below the depth of the corrugations, adding water, and regrading. Compacted aggregate base, size No. 53 or size No. 73 should be selected to resist washboarding.

52-6.02 Asphalt Pavement

1. Block Cracking. Block cracking is a non-load-related distress that generally divides the pavement into blocks that range in size from 0.1 m^2 to 10 m^2. Block cracking is mainly caused by shrinkage of the pavement combined with temperature cycling. On multi-lane pavements, block cracking can only occur in the passing lane as it is a non-load-related distress. Traffic loadings in the travel lane tend to relieve the shrinkage stresses. The recommended treatment for block cracking is to remove the existing surface course by asphalt milling 25 mm or 38 mm and overlay the milled surface.

2. Flushing. Flushing is defined as free binder or binder and fine aggregate mastic which migrates to the surface of the pavement forming darkened areas principally in the wheel paths. Severe flushing creates a tacky surface and may even run downhill. Flushing may occur due to excessive binder or moisture, low air voids in the mix, or stripping. The recommended treatment for flushed areas is to mill the mixture causing the flushing prior to overlaying of the pavement. Asphalt milling to the depth of the mixture causing the flushing should be used prior to overlaying.

3. Frost Heave. Frost heave is defined as the differential displacement of the surface when a frost sensitive subgrade freezes. Frost heave is accentuated by moisture in the subgrade/subbase. Surfaces allowing large amounts of water due to low density/high voids, segregated surfaces, etc., to enter the pavement structure are especially prone to frost heave. Frost heave usually dissipates during the spring when the subgrade/subbase thaws. Future occurrences of frost heave may be lessened by covering the surface to minimize the amount of water entering the pavement system.

4. Longitudinal Cracking. Longitudinal cracks are cracks in the pavement surface generally parallel to the centerline of the roadway. Longitudinal cracks may be caused by cracks reflecting through a pavement surface, poor construction practice at longitudinal joints, or by wheel loadings. The recommended treatment for longitudinal cracking is to seal, rout and seal, or in severe situations, remove and replace the distressed area.

5. Polishing. Polishing is caused by the abrasion of the surface to the extent that the pavement surface becomes slick. Polishing of the surface aggregate is traffic dependent. The INDOT *Standard Specifications* allow only certain types of aggregates for surface courses dependent on the number of ESALs specified. The recommended treatment for polished surfaces is to remove the polished areas by scarification/profile milling prior to placing an overlay.

6. Raveling. Raveling is the loss of aggregate from the upper pavement layer exposed to traffic. Raveling may be caused by insufficient binder material, insufficient compaction, or segregation of the mixture during construction of the pavement. The recommended treatment for severe cases of raveling is to remove the surface course by asphalt milling 25 mm or 38 mm prior to placing an overlay. The recommended treatment for moderate cases of raveling is to overlay the roadway. The recommended treatment for minor cases of raveling is to spot seal raveled areas.

7. Reflective Cracking. Reflective cracks are those cracks that have developed in a overlay resulting from the movement of the joints and cracks in the underlying pavement. Cracking occurs when the movement of the underlying pavement exceeds the elasticity of the overlay resulting in the migration of the crack pattern from the underlying pavement to the surface of the pavement. Extremely low temperatures or sudden drops in temperature can create tensile stresses in the pavement beyond the tensile properties of the binder material. Differential movement at the existing crack as traffic travels across the crack increases the stress in the overlay. If reflective or transverse cracking is left unchecked, the pavement adjacent to the area of the cracks will further deteriorate by raveling or stripping, and will result in a rough riding surface.

   The recommended treatment for low-severity reflective cracking is to seal the cracks with a sealant material to minimize the intrusion of water. The recommended treatment for moderate to high severity occurrences of reflective cracking include sawing / routing and resealing the existing cracks, or asphalt removal milling and placement of an overlay. An appropriate slab reduction should be considered to minimize the movement of the PCC base from traffic loadings.

8. Rutting. Rutting is longitudinal deformation of the pavement in the wheel tracks. Rutting is the result of an improper mix design, poor compaction, a soft subgrade, or stripping (water damage) in the underlying layers of the pavement. The recommended treatment for rutting is to mill and replace the deformed material. The type of milling specified is dependant on the average rut depth as determined by the INDOT pavement management system. Scarification/profile milling is used from minor rutting less than or equal to 5 mm. Asphalt milling is used for severe rutting greater than 5 mm. For minor rutting, preventative maintenance alternatives such as micro surfacing may be considered.

9. Shoulder Drop-off. Shoulder drop-off is the difference in elevation between the driving lanes and the shoulders due to settlement or erosion. The recommended treatment for severe shoulder drop-offs (> 25 mm) is to fill in the depressed areas with compacted aggregate size No. 53 or HMA patching materials.

10. Stripping. Stripping is the debonding of the binder film from the aggregate. Visible signs of stripping include surface delamination, raveling, potholing, or surface discoloration. Stripping is an aggregate-dependent distress. Stripping is caused by a combination of heat, pressure, and water. Sources of heat, water, and pressure are, rain, summer sun, and heavy trucks. The recommended treatment for stripping is to remove the stripped material by asphalt milling and then to overlay the milled surface.

11. Thermal Cracking. Thermal cracking is transverse cracking of a pavement. The cause of thermal cracking is binder material that was originally too hard or has age-hardened. The recommended treatment for severe cases of thermal cracking is to remove the surface course by asphalt milling 25 mm or 38 mm prior to placing an overlay. Minor to moderate areas of thermal cracking should be sealed.

12 Alligator/Fatigue Cracking. Alligator/Fatigue cracking occurs with repeated traffic loadings and is considered to be a structural failure of pavement. The cracking is best described as spider type cracking on the surface of the pavement and typically occurs in the wheel paths. The recommended treatment for the cracking is to remove and replace the failed areas by milling, and then place a structural overlay on the pavement.

13. Weathering. Weathering is hardening and loss of binder material due to oxidation. The hardening and the loss of the binder material may cause the displacement of aggregate particles from the riding surface similar to raveling. The recommended treatment for this distress is to seal coat or overlay the surface.

52-6.03 Concrete Pavement

1. Alkali-Silica Reactivity (ASR). ASR occurs when silica in the aggregates and alkali in the cement react in the presence of water to form a gel-like substance. The gel-like substance absorbs moisture and swells causing the concrete surface to crack in a maplike pattern. During later stages of ASR distress, the surface will begin to spall. The recommended treatment for pavements in advanced stages of ASR distress is an overlay. Slab reduction techniques, such as crack-and-seat or rubblization, should be considered for high volume roads in accordance with the INDOT *Standard Specifications*.

2. Blowups. Blowups are isolated and sudden elevation changes along the profile of the roadway. Severe blowups occur when adjacent panels rise off the ground in a tent like manner. Blowups are caused by the build up of compressive stresses in the pavement due to the infiltration of incompressible materials into the joints. Blow ups occur usually at a transverse crack or joint that is not wide enough to accommodate the expansion of the concrete slab. Some coarse aggregates exposed to freeze-thaw conditions in the presence of free moisture greatly influence the growth of the concrete pavement. In addition, build up of water within the pavement structure acts as a lubricant and catalyst for blowups to occur. The recommended treatment for repairing blowups is to remove the affected area and patch with PCCP patching.

3. Corner Breaks. Corner breaks are random diagonal cracks at the intersection of transverse and longitudinal joints. Corner breaks are caused by load repetition in combination with loss of support, poor load transfer across joints or thermal curling, or moisture-warping stresses. The recommended treatment for corner breaks is to remove the affected area for a full lane width and patch with PCCP. Pavements with numerous corner breaks should be rehabilitated by using a slab reduction technique and an overlay.

4. "D" Cracking. "D" cracking usually occurs at transverse joints caused by the expansion of the aggregate in PCCP. “D” cracking is caused by an expansive coarse aggregate in the PCCP under freeze thaw conditions, and starts near the bottom of the slab and progresses up through the concrete. Symptoms of "D" cracking in jointed PCCP are spider web cracks at the transverse joints. "D" cracking detected at some surface locations generally indicates that numerous other locations are also "D" cracking. The recommended treatment for PCCP with "D" cracking is to use a slab reduction technique and an overlay.

5. Faulting. Faulting is a differential in elevation of two adjacent slabs. Faulting can occur at joints or at random transverse cracks in PCCP. Faulting is caused by a loss of

aggregate or mechanical load transfer and the loss of support or the build-up of material under one of the slabs, causing the slabs to be displaced relative to each other. The recommended treatment for isolated faulted areas is to remove the affected areas and patch with PCCP patching, or to use retrofit dowel bars while reestablishing subgrade support and correcting surface profile. Pavements with significant faulted areas should be rehabilitated by using a slab reduction technique and an overlay.

6. Joint Failure. Joint failure is a contraction joint that has cracked or spalled, or generally does not perform as desired. Joint failures are caused by misaligned dowel bars during construction or by fatigue from repetitive loads. The recommended treatment for localized joint failure is to remove the affected areas and patch with PCCP patching. Pavements with significant areas of joint failure should be rehabilitated by using a slab reduction technique and an overlay.

7. Joint Seal Failure. Joint seal failure is the loss of adhesion between the seal material and the joint faces, puncturing of the seal material, or displacement of the seal material. The recommended treatment for failed seal material is to remove the existing joint seal material, clean the joint faces, and reseal the joint.

8. Longitudinal Cracking. Longitudinal cracks are random cracks oriented predominantly along the pavement. Longitudinal cracks may occur because of the loss of support or the improper sawing of the joints. Longitudinal cracking is particularly detrimental because it allows water flowing across the pavement to enter the pavement structure. Isolated areas of longitudinal cracking should be repaired in accordance with the INDOT *Standard Specifications*. PCCP with excessive areas of longitudinal cracking should be rehabilitated by using a slab reduction technique and an overlay.

9. Polishing. Polishing is caused by the abrasion of the surface to the extent that the surface becomes slick. Polishing is traffic dependent. The recommended treatment for polished surfaces is to diamond grind the PCCP surface or PCCP mill and overlay.

10. Poor Rideability. Poor rideability is the result of a roughened pavement caused by poor construction techniques, unstable subgrade, or the deterioration of the riding surface. Poor ride quality may be corrected by diamond grinding the surface as long as no other distresses are present in the pavement structure. Appropriate remediation techniques should be considered when other distresses are present.

11. Popouts. Popouts are small holes, 10 to 40 mm in diameter, in the pavement surface. Popouts are caused by soft or deleterious aggregate material in the PCCP surface that disintegrates in the presence of water or freeze-thaw conditions. Generally, popouts are considered an aesthetic problem and are not significantly detrimental to the pavement's performance. Popouts are not specifically repaired.

12. Punchouts. Punchouts are failures in the pavement caused by insufficient structural strength at localized areas of the pavement. These failures appear as depressions or holes in the pavement. The recommended treatment for localized punchouts is to remove the affected area and patch with PCCP patching. Pavements with significant areas of punchouts should be rehabilitated by using a slab reduction technique and an overlay.

13. Transverse Cracking. Transverse cracks are random cracks oriented predominantly across the pavement away from planned joint locations. Transverse cracking is caused by poor construction techniques or improper joint design. Poor support, a poor mix design, improper mixture, improper subbase placement, or untimely sawing of the pavement may also cause random transverse cracking. The recommended treatment for random transverse cracking is to remove and replace the affected areas or a slab reduction technique and an overlay.

14. Scaling. Scaling is the local flaking or peeling of a finished surface of hardened concrete as a result of freezing and thawing. Scaling may be caused by improper mix designs, over finishing during construction, or improper curing and the application of excessive or detrimental deicing chemicals. The recommended treatment for severe cases of scaling is to mill the surface and overlay the pavement. Isolated areas of severe scaling may be corrected by diamond grinding. Moderate scaling is not repaired.

15. Spalling. Spalling is the raveling of concrete at joint faces or steel reinforcement. Spalling may be due to improper sawing, improper concrete curing, excessive stresses at the joint, or poor installation of load transfer devices. The recommended treatment for severe cases of spalling is to remove and replace the affected areas and replace the joint material. Moderate spalling is not specifically repaired.

16. Structural Failure. Structural failure is a load-related distress indicated by map cracking of the entire pavement and is caused by insufficient thickness. The recommended treatment for structural failure is replacement of the pavement.

52-7.0 PAVEMENT SCOPING

Candidate projects are proposed by the Program Development Division or an LPA and evaluated for pavement treatment. Project scopes may be driven by non-pavement issues such as budget constraints, capacity, safety, drainage, short or long term needs, truck loadings, or geometric deficiencies. The intended project scope and its impacts on the existing or new pavement structure should be understood prior to developing the pavement treatment recommendation. Pavement distresses described in Section 52-6.0 should be considered in determining the appropriate treatment for the project. Additional pavement investigation (i.e. core analysis, FWD, condition survey, etc.) of existing pavements may be required to determine the appropriate pavement treatment including any requirements for the milling of the existing pavement. All asphalt pavements will be milled prior to placing an overlay.

A pavement replacement project includes removal of the existing pavement structure, including any subbase, and preparation of the subgrade prior to placing a new pavement structure. Pavement damage due to structural deficiencies should be reconstructed. A pavement that is structurally sufficient is a candidate for a rehabilitation-type project, a preventative-maintenance or functional overlay type project. A pavement requiring 50 percent or more of it to be replaced is generally considered for reconstruction. All work being proposed for a project (i.e. sewer installation, added travel lanes, curve corrections, etc.) should be considered when evaluating the existing pavement.

A rehabilitation project utilizes the existing pavement structure to significantly extend the service life of an existing pavement. The pavement work on rehabilitation projects may include milling of the existing pavement, PCCP slab reduction, the placement of an overlay, or a combination of these elements.

A partial 3R project is intended to preserve and extend the service life of the mainline pavement and shoulders. A partial 3R project should be designed in accordance with Chapter Fifty-six. The pavement work on Partial 3R projects generally restores the riding or surface characteristics of the pavement to a near new condition. Partial 3R projects include preventative maintenance, functional, or structural pavement treatments as described in Section 52-7.04.

Pavement recommendations are not required for public road approach pavements or wedges on a bridge overlay project. The pavement designs for public road approach pavements should be in accordance with the INDOT *Standard Drawings*. The wedges should compensate for the bridge overlay grade raise. Detailed pavement designs and analyses should be completed for other types of projects.

52-7.01 Pavement on New Alignment

A preliminary pavement thickness of 350 ± 50 mm should be used during the scoping of the project.

52-7.02 Pavement on Replacement Projects

A statement should be made that the existing pavement structure must be removed and replaced. The preliminary pavement thickness for the replacement projects will be 350 ± 50 mm.

52-7.03 Rehabilitation Project

Rehabilitation projects will include milling of an existing asphalt pavement. The pavement scope will include an approximate depth of milling.

Where rubblization is utilized as a slab reduction technique, the pavement scope should state that a geotechnical investigation is required. For a rubblization project, the preliminary pavement thickness for the replacement projects will be 350 ± 50 mm.

For concrete pavements where a slab reduction technique is not used, the scope should include elements required to correct the surface deficiencies including milling and overlay requirements.

52-7.03(01) Falling-Weight Deflectometer Testing

The pavement designer should evaluate the need for FWD testing pertaining to concrete, asphalt, or composite pavements. The FWD data is used to evaluate the structural adequacy of an existing pavement section, to evaluate pavement shoulder adequacy for temporary traffic, or to provide an estimated quantity of underseal to be included in the plans for PCCP over dense graded subbase. See Figure 52-7A for a sample Instructions for Listing Falling-Weight Deflectometer (FWD) Testing Request form.

52-7.03(02) Pavement Coring

The pavement designer should evaluate the need for pavement coring. If cores are required, the information should be requested well in advance of the date it is required for project development.

52-7.04 Partial 3R Projects

The types of partial 3R projects are as follows:

52-7.04(01) Preventative Maintenance (PM) Treatment

A PM treatment is intended to arrest light deterioration, retard progressive damage and reduce the need for routine maintenance. The proper time for PM is before the pavement experiences severe distress, structural problems, and moisture or aging-related damage. These activities can be cyclical in nature and may correct minor deficiencies for either HMA or PCCP projects.

The HMA PM treatments most commonly used are chip seals, crack sealing, microsurfacing, surface milling and thin HMA inlay, thin HMA overlay, sand seals, routing and sealing cracks or joints.

The PCCP PM treatments most commonly used are sawing and sealing joints, retrofit joint load transfer, diamond grinding, and Concrete Pavement Restoration (CPR).

All treatments are described in detail in Section 52-11.0.

52-7.04(02) Functional Treatment

A functional treatment of an asphalt or PCCP pavement restores pavement smoothness to near new condition on structurally sufficient pavement.

An HMA functional treatment consists of an Intermediate course and a Surface course. The placement of the Intermediate course should be preceded by milling. The pavement should be designed in accordance with Section 52-9.0.

A PCCP functional treatment may consist of Concrete Pavement Restoration (CPR) to be used to correct functional distresses. CPR may consist of crack sealing, partial and full depth patching, resealing of joints, undersealing, diamond grinding, or retrofit dowel bars. An HMA overlay may also be used.

52-7.04(03) Structural Treatment

A structural treatment of an asphalt or PCCP pavement strengthens the existing structure to current design requirements and restores the pavement smoothness to a new condition.

An HMA structural treatment will consist of Base, Intermediate, and Surface courses, with milling of the existing pavement. The pavement should be designed in accordance with Section 52-9.0.

A PCCP with structural failure may be rehabilitated with slab reduction techniques such as cracking and seating or rubblization and overlay. For rubblization, the overlay thickness will depend on traffic counts and the Materials and Tests Division's Geotechnical Section's recommendations. The HMA overlay pavement section for rubblization should be designed in accordance with Section 52-9.02(05).

52-7.05 Milling of Pavements

Asphalt or concrete pavements may be milled to remove distressed layers of material, make crown corrections, maintain curb heights or vertical clearances, scarify existing surfaces, surface profiling, removal of asphalt overlays, or to provide pavement transitions in accordance with the INDOT *Standard Specifications*. The five types of milling of pavements and their general usages are as follows:

1. Asphalt milling is used to remove distresses near the surface of the pavement or prior to placing HMA inlays.

2. Asphalt scarification/profile milling is used to roughen the surface or remove excessive crack sealant prior to placing HMA overlay.

3. Asphalt removal milling is used to remove asphalt materials down to a concrete or brick base.

4. PCCP milling is used to roughen the existing surface or to provide crown corrections prior to placing an overlay.

5. Transition milling is used to provide transitions to adjoining sections.

52-7.05(01) Asphalt Milling

Asphalt milling is intended to remove material from an existing pavement to a specified average depth by milling the surface and creating a uniform profile. An average depth of milling should be specified depending on the condition of the pavement or project requirements. Asphalt milling is used as follows:

1. prior to placing HMA inlays;
2. removal of stripped or distressed asphalt;
3. correction of substandard cross slope or crown conditions;
4. profile corrections; or
5. maintaining vertical clearances or curb heights.

The average milling depth specified will be sufficient to accommodate the HMA Inlay or the removal of distressed materials. The average milling depths to be used will be 25, 38, 50, 75 or 100 mm.

For variable milling depths to correct cross slope deficiencies, the limits and associated milling depths must be shown on the typical cross sections in accordance with Section 52-13.0.

52-7.05(02) Asphalt Scarification/Profile Milling

Asphalt scarification/profile milling is used to provide a roughened texture to an existing surface. Asphalt scarification/profile milling will remove crack sealant to prevent slippage of the overlay materials, roughen the existing surface that has polished due to traffic or correct minor profile or cross slope deficiencies. Correction of minor cross-slope deficiencies is limited to 5 mm average rut depth determined by the INDOT pavement management system. Milling operations to correct pavement conditions that require deeper milling shall be in accordance with Section 52-7.05(01).

Asphalt scarification/profile milling is used to prepare an existing pavement for a single course HMA overlay. Asphalt scarification/profile milling is used to prepare an existing pavement for functional overlays when the existing pavement has excessive crack sealant or requires minor profile corrections.

52-7.05(03) Asphalt Removal Milling

Asphalt removal milling is used to remove an entire asphalt overlay from a concrete or brick base. The project designer will designate the approximate existing asphalt thickness on the typical sections in the plans.

52-7.05(04) PCCP Milling

Portland cement concrete milling is intended to remove materials from an existing PCC pavement to a specified average depth to create a uniform profile. An average depth of milling should be specified depending on the condition of the pavement or project requirements. Portland cement concrete milling is used as follows:

1. correction of substandard cross slope or crown conditions;
2. profile corrections;

3. maintaining vertical clearances or curb heights; or
4. preparation for an HMA overlay.

The project designer will designate the average milling depth on the typical cross sections on the plans. For variable milling depths to correct cross slope deficiencies, the limits and associated milling depths must be shown on the typical cross sections on the plans in accordance with Section 52-13.0.

52-7.05(05) Transition Milling

Transition milling is used to provide a connection between an HMA overlay and an adjoining pavement, driveway, paving exception, or public road approach. The transition slope and notch depth in the existing asphalt or concrete pavement will be in accordance with the INDOT *Standard Drawings*.

52-8.0 PAVEMENT DESIGN PROCEDURAL GUIDELINES

The pavement designer should determine the pavement type and thickness of the pavement structure based on subgrade conditions, materials, ESALs, and economic consideration. The pavement designer is also responsible for determining the grade of binder for QC/QA-HMA projects.

52-8.01 Pavement Designer

The Materials and Tests Division's Pavement Design Engineer has responsibility for the pavement design of all Central-Office-developed projects and district-developed projects with 5000 AADT or greater, or 500 ADTT Class 5 or greater. For district-developed projects with less than 5000 AADT and 500 ADTT, the pavement designer is the development engineer or head design engineer. The Pavement Design Engineer is also available for consultations with the districts for projects with less than 5000 AADT or 500 ADTT.

For LPA projects, the LPA's agent is the pavement designer.

52-8.02 Pavement Design Requests

Pavement design requests are to be submitted by the project manager to the Pavement Design Engineer, the district's Development Engineer or Head Design Engineer. All submittals will be prepared on the Pavement Design Request -- INDOT Project form in accordance with Section 52-14.0. Instructions for the completion of the form are included in Section 52-14.0.

All LPA projects utilizing federal funds designed by LPAs or their agents should be submitted to the INDOT Pavement Design Engineer for approval. The proposed pavement design should be prepared on the Pavement Design Request -- LPA Project form in accordance with Section 52-14.0. Instructions for the completion of this form are included in Section 52-14.0. A hard copy of the DARWin output used to design the pavement should be submitted with this form.

52-8.03 DARWin Inputs

52-8.03(01) Simple ESAL Calculation

AASHTO's pavement design computer program, DARWin, should be used for the design of pavements. Recommended factors to be used with the Design Guide and input in DARWin are as follows:

1. Performance Period.

PCCP Pavement	30 years
PCCP over Existing Pavement	25 years
HMA Pavement	20 years
HMA Overlay on Rubblized PCC	20 years
HMA Overlay on Cracked & Seated PCC	15 years
HMA Overlay over Asphalt	15 years
HMA Overlay over PCCP	12 years

2. Two Way Traffic (AADT). The total yearly volume in both directions of travel divided by the number of days in a year.

3. Number of Lanes in Design Direction. The total number of through lanes in the design direction.

4. Percent Trucks in the Design Lane.

   100% for 2-Lane Roads
   90% for 4-Lane Roads
   80% for Roads of 6 Lanes or More

5. Percent Trucks in Design Direction. For the percent trucks of AADT in the design direction use 50%

6. Percent Heavy Trucks. The amount of trucks, FHWA Class 5 or greater, as a percentage of the AADT.

7. Average Initial Truck Factor (ESALs per Truck) -- Equivalent Single Axle Load (ESAL). ESAL is defined as the amount of damage experienced by the subgrade due to a single 80-kN (18-kip) axle load. Damaging effects of any axle load may be represented by an equivalent number of 80-kN (18-kip) ESALs. The damage varies exponentially with axle loads different than 80 kN (18 kips). The average ESAL per truck calculated from data collected on Indiana roads is shown in Figure 52-8A.

8. Annual Truck Factor Growth Rate. Truck loading increases are computed periodically by INDOT through research projects and are reflected in the initial ESALs per truck. For DARWin input use 0.0%.

9. Annual Truck Volume Growth Rate. The average annual increase in trucks. If the 20-year projected AADT is known, the growth factor is calculated using the equation as follows:

$$Growth\,Factor = \left(\frac{Design\,Year\;AADT}{Current\;Year\;AADT}\right)^{0.05} - 1$$

10. Growth. Use compound growth rate.

11. Total Calculated Cumulative ESALs. The total estimated ESALs during the design life of the project calculated by the DARWin program.

52-8.03(02) Flexible Pavement Structural Design

1. Total Calculated Cumulative ESALs. The total estimated ESALs during the design life of the project calculated by the DARWin program.

2. Serviceability. The Present Serviceability Index (PSI) is a subjective rating of pavement ride quality. The scale varies from 5 to 0 where 5 represents a perfect pavement and 0 represents a failed and totally impassable pavement. The original PSI concept was determined by averaging the results of a panel of raters riding on the pavement. PSI

represents a means of using objectively obtained data to estimate a subjectively based rating.

a. Initial Serviceability. New pavements are assumed to have an initial serviceability or PSI of 4.5.

b. Terminal Serviceability. A rural pavement is considered to have reached its terminal serviceability when the index reaches 2.5 for routes functionally classified as Major Collectors or higher, and 2.0 for Minor Collectors or lower. An urban pavement is considered to have reached its terminal serviceability when the index reaches 2.5 for routes functionally classified as Arterials, and 2.0 for routes functionally classified as Collectors or below.

3. Reliability Level. Reliability is the probability that a roadway will achieve its design life. A higher reliability factor results in a greater chance that the pavement will be above the terminal serviceability at the end of the projected design life. Reliability factors used for Indiana pavements are as follows:

Interstate Routes:	98%
Urban Arterials:	95%
Other Routes:	90%

4. Overall Standard Deviation. This value should be 0.35.

5. Roadbed Soil Resilient Modulus. The soil support value is given in the geotechnical report in terms of a California Bearing Ratio (CBR). The CBR value is converted to a Resilient Modulus by multiplying the CBR by 10,500 to obtain kilopascals. (The CBR is converted to a Resilient Modulus by multiplying the CBR by 1500 to obtain psi)

6. Stage Construction. Pavements are typically designed and constructed for their full 20-year expected life. Stage construction may be considered where a planned overlay is constructed at year *X* to complete the 20-year design. Typically, stage construction is not considered and a value of 1 is used.

DARWin reports a design structural number for HMA pavements. The structural number is equal to the summation of the thickness of each course of material times its layer coefficient per 25 mm of material. This summation should be equal to or greater than the design structural number. The following layer coefficients are typically used for design values based on a 25 mm thickness of material.

HMA Surface	0.34

HMA Intermediate	0.36
HMA Base	0.34
Rubblized Concrete	0.20
Compacted Aggregate Base	0.14

The design thickness of each HMA mixture (surface, intermediate, and base) or compacted aggregate base in accordance with the Typical Sections shown in Section 52-13.0 are input into DARWin to calculate the equivalent structural number of a proposed section to compare to the computed design structural number determined by DARWin.

52-8.03(03) Rigid Pavement Structural Design

1. Total Calculated Cumulative ESALs. The total estimated ESALs during the design life of the project calculated by the DARWin program.

2. Serviceability. The Present Serviceability Index (PSI) is a subjective rating of pavement ride quality. The scale varies from 5 to 0 where 5 represents a perfect pavement and 0 represents a failed and totally impassable pavement. The original PSI concept was determined by averaging the results of a panel of raters riding on the pavement. PSI represents a means of using objectively obtained data to estimate a subjectively based rating.

   a. Initial Serviceability. New pavements are assumed to have an initial serviceability or PSI of 4.5.

   b. Terminal Serviceability. A rural pavement is considered to have reached its terminal serviceability when the index reaches 2.5 for routes functionally classified as Major Collectors or higher, and 2.0 for Minor Collectors or lower. An urban pavement is considered to have reached its terminal serviceability when the index reaches 2.5 for routes functionally classified as Arterials, and 2.0 for routes functionally classified as Collectors or below.

3. 28-Day Mean PCC Modulus of Rupture. This value should be 4500 kPa.

4. 28-Day Mean Elastic Modulus of Slab. This value should be 23 500 000 kPa.

5. Mean Effective *k*-Value The soil support value is given in the geotechnical report in terms of a California Bearing Ratio (CBR). The modulus of subgrade reaction *k* for PCCP, is dependent upon several factors besides roadbed soil resilient modulus. It should be determined by means of the procedures outlined in the AASHTO *Pavement*

Design Guide Part II, Chapter 3, Section 3.2.1, or the *Supplement* to the *AASHTO Guide,* Table 11.

6. Reliability Level. Reliability is the probability that a roadway will achieve its design life. A higher reliability factor results in a greater chance that the pavement will be above the terminal serviceability at the end of the projected design life. Reliability factors used for Indiana pavements are as follows:

Interstate Routes:	98%
Urban Arterials:	95%
Other Routes:	90%

7. Overall Standard Deviation. This value should be 0.35.

8. Load Transfer Coefficient, *J*. All pavements will be doweled. The J value should be as follows:

With Integral Curbs:	2.8
With Tied Concrete Shoulders:	2.8
With 4.2 m Extended Lane:	2.8
With HMA Shoulders:	3.2

9. Overall Drainage Coefficient, C_d. This value should be 1.

10. Calculated Design Thickness. DARWin reports a design thickness of PCCP. The plan thickness to be used is shown in Figure 52-8B, PCCP Thickness.

52-9.0 PAVEMENT CROSS SECTION DESIGN

The Materials and Tests Division's Pavement Design Engineer recommends the pavement type selection for all projects developed in the Central Office, and for district-developed projects where the AADT is 5000 or greater, or the ADTT is 500 or greater. For district-developed projects with AADT less than 5000 or ADTT less than 500, the District will be recommending the selection. For LPA projects, the LPA or its designated representative will provide the selection.

For all selections, several factors should be considered when selecting pavement types. These include, but are not limited to the scope of the project, Life-Cycle Costing analysis, and adjoining pavement types. For rehabilitation and partial 3R projects, the most important factor to consider is the condition of the existing pavement and the scope of the project.

The pavement designer should design pavement sections for the types of projects determined by the scope of work. New or proposed replacement or reconstructed pavements are typically designed for 20 to 30 year pavement design lives. Functional or structural partial 3R projects or rehabilitation projects are typically designed for 10 to 30 year pavement design lives dependent on the base preparation. Preventative Maintenance partial 3R projects are intended to maintain the pavement in a serviceable condition for 4 to 12 years depending on the treatment.

A new pavement structure is designed for projects where a new roadway will be constructed or a replacement pavement structure is designed where the existing pavement is being removed and replaced. Pavements should be designed according to the AASHTO *Guide for Design of Pavement Structures* and should be detailed as shown in the Typical Pavement Sections included in Section 52-13.0. An approved geotechnical report and traffic data will be completed prior to submitting a pavement design request for all new and replacement pavement structures.

Rehabilitation designs are the most varied and complicated of all pavement designs. An HMA overlay or PCCP over pavement is used where the existing pavement is not structurally sufficient. Rehabilitation of asphalt pavements involves the placement of an overlay. Rehabilitation of PCCP may involve an overlay or an overlay over PCCP with slab reduction. Rehabilitation of composite pavements should consider the required treatments for both asphalt and portland cement concrete pavements.

52-9.01 Aggregate Pavements

Requirements for Compacted Aggregate Pavement (CAP) are shown in the INDOT *Standard Specifications*. CAP is constructed on prepared subgrade.

The subgrade should be designed in accordance with the Geotechnical Report and constructed in accordance with the INDOT *Standard Specifications*. The geotechnical recommendations may include a soil modification or stabilization process, Subgrade Treatment, or a Compacted Aggregate Stabilization Layer.

The designed thickness of CAP determined by DARWin is placed on the subgrade. The minimum CAP thickness is 300 mm. The minimum CAP thickness is composed of 100 mm of compacted aggregate surface size No. 73 on 200 mm of compacted aggregate base size No. 53.

52-9.02 HMA Pavements

Requirements for HMA Pavements are shown in the INDOT *Standard Specifications*. HMA is constructed on prepared subgrade.

The subgrade should be designed in accordance with the Geotechnical Report and constructed in accordance with the INDOT *Standard Specifications*. The Geotechnical Report will include recommendations for the subgrade treatment. The designed thickness of HMA or HMA on compacted aggregate base determined by DARWin is placed on the subgrade. The minimum HMA or composite HMA and compacted aggregate thickness is 300 mm.

52-9.02(01) Mixture Designations

The project designer should determine whether to use Quality Control/Quality Assurance (QC/QA) HMA mixtures, or HMA mixtures, both as described in the INDOT *Standard Specifications*. The criteria for using QC/QA-HMA mixtures or HMA mixtures are based on the quantity of material to be used or at high stress locations.

52-9.02(02) QC/QA-HMA Mixtures

QC/QA-HMA is specified for all but small quantity projects or where heavy traffic conditions require that the mixture be engineered to withstand the traffic induced stresses. QC/QA-HMA should be specified for the following:

1. A mixture that exceeds one sublot of material. The INDOT *Standard Specifications* defines a sublot as 600 Mg for surface courses and 1000 Mg for base or intermediate courses.

2. Urban rehabilitation projects that include multiple- and closely-spaced intersections throughout the limits of the project.

3. Urban intersection projects with ESALs > 3,000,000, that incur increased stresses in the pavement caused by heavy, slow moving, and stopped traffic conditions. Mixtures placed off of the mainline are not required to be QC/QA. In cases where small quantities of mixture off of the mainline are required the project designer should evaluate the number of mixtures specified to limit the number of mixture designations required in the contract. Small quantity mixture designations should be designated as in Section 52-9.02(03) or included in like QC/QA items on the mainline.

4. Rural intersection projects with ESALs > 3,000,000, that incur increased stresses in the pavement caused by heavy, slow moving, and stopped traffic conditions and are not part of an adjoining rehabilitation project. Mixtures placed off of the mainline are not required to be QC/QA. In cases where small quantities of mixture off of the mainline are required the project designer should evaluate the number of mixtures specified to limit the number of mixture designations required in the contract. Small quantity mixture designations should be designated as in Section 52-9.02(03) or included in like QC/QA items on the mainline.

5. The project is being phased as part of an overall project that would have quantities meeting the minimum sublot criteria.

6. All open graded mixtures, Intermediate OG 19.0 and OG 25.0, are independent of the ESALs and quantity.

The pay items for QC/QA-HMA mixtures specify the ESAL category, the high temperature performance grade, the mixture course, and the nominal size of the mixture. The size of the mixture is always specified with a metric designation to agree with the AASHTO SUPERPAVE designations.

An example of a QC/QA-HMA pay item is shown below.

QC/QA-HMA,	_______,	______,	_______,	______ mm
	(ESAL Category)	(PG)	(Course)	(Mixture Size)

The ESAL categories are listed in Figure 52-9A, ESALs for QC-QA HMA Mixtures.

The high temperature performance grade binder will vary depending on various factors included in Section 52-9.02(04), and will be 64, 70, or 76. However, for type OG mixtures, the high temperature performance grade binder is always 76. The low temperature performance grade is not a design consideration. A value of -22 is always specified in the INDOT *Standard Specifications.*

The course designation is the specific mixture and will be Surface, Intermediate, or Base.

The mixture designation will be the mixture designed. Surface courses will be either 9.5 or 12.5 mm mixtures. Intermediate courses will be 12.5, 19.0, 25.0, OG 19.0, or OG 25.0 mm mixtures. Base course will be 19.0 or 25.0 mm mixtures.

EXAMPLE: The pay item QC/QA-HMA, 4, 76, Surface, 9.5 mm represents a QC/QA HMA-mixture with less than 30,000,000 ESALs, a PG 76 high temperature binder, a Surface course, and a Mixture Designation size of 9.5 mm.

The project designer should use the pay item descriptions shown for QC/QA-HMA mixtures in the INDOT *Standard Specifications*.

52-9.02(03) HMA Mixtures

HMA is specified for small-quantities projects or where construction constraints require that the material be placed in non-uniform widths and thicknesses. HMA should be specified for a pavement section where none of the mixtures exceed one sublot of material.

For all miscellaneous mixtures such as HMA for wedge and leveling, HMA for approaches, etc., the project designer should specify the applicable mixtures as listed in the INDOT *Standard Specifications.*

The pay items for HMA mixtures specify the type and course of material.

An example of an HMA pay item is shown below.

HMA, ______, _______
(Course) (Type)

The mixture type is determined from ESALs calculated for the project's pavement design. The type categories for HMA mixtures are listed in Figure 52-9B, ESALs for HMA Mixtures.

The course designation is the specific mixture and will be Surface, Intermediate, or Base.

EXAMPLE: The pay item HMA, Type B, Surface represents an HMA mixture for the range of $0.3 \leq \text{ESAL} < 3$, and Surface course.

The project designer should use the pay item descriptions shown for HMA mixtures in the INDOT *Standard Specifications*.

52-9.02(04) PG Binder and ESALs

Performance Graded (PG) Binders for QC/QA mixtures are designed based on their performance-related properties determined for the project's climate (temperature) and location within the pavement structure. Base mixtures may require a lower high temperature grade than the surface and intermediate mixtures. Secondly, the PG binder should be adjusted based on the speed and amount of traffic for the project. For HMA overlays, the type and condition of the existing pavement should also be considered. The computer program LTPPBIND should be used to select the grades of the PG Binder for specific projects. LTPPBIND may be downloaded from the web site http://www.tfhrc.gov/pavement/ltpp/ltppbind.htm.

PG binders are identified with high and low Celsius temperature values. For example, PG 70-22 identifies 70°C as the high temperature design value and -22°C as the low temperature design value. The high temperature value is the average seven-day maximum pavement temperature. The low temperature value is the lowest air temperature recorded at the weather station(s) nearest the project site.

The binder selection reliability is used to indicate the probability that the design high and low temperatures will not be exceeded during the design life. Values of 64, 70, or 76 should be used for the high temperature design and a value of -22 will be used for the low temperature design. The value selected for high temperature should be evaluated for 98% reliability. However, temperature values meeting 90% reliability may be considered for low-ESAL roadways.

The PG binder for QC/QA projects will be identified in the pay item designation. The INDOT *Standard Specifications* specify the PG binder for all non-QC/QA mixtures.

The ESALs should be calculated using DARWin and the project's traffic data. ESALs should be calculated for 20 years regardless of the project's design life. ESALs should be rounded up to the nearest 50,000. The design level for ESALs will be identified in the pay item designation.

Where shoulders are constructed full depth or where the shoulders will be used for maintenance of traffic operations, the shoulder ESALs will be the same as those for the mainline. Where shoulders are not constructed full depth and will not be used for maintenance of traffic operations, the ESALs will be 200,000.

For projects with HMA mixtures where ESALs have not been calculated as part of the pavement design process, the ESAL value from Figure 52-9B will be used to select the appropriate pay item designation.

52-9.02(05) Asphalt Pavement Rehabilitations

Asphalt pavement structures identified as having distresses listed in Section 52-6.02 should be rehabilitated by means of the treatment recommended therein. The pavement designer will specify the type and limits of milling, and the type and thickness of any overlay. The existing pavement plus the proposed rehabilitation will be designed for structural sufficiency by computing the structural number of the existing pavement and comparing this number with the required structural number for the project. The layer coefficients for existing asphalt pavement should be reduced according to the AASHTO *Guide for Design of Pavement Structures,* Part III, Chapter 5, Table 5.2, Suggested Layer Coefficients for Existing AC Pavement Layer Materials.

52-9.02(06) Shoulders

For HMA shoulders of less than 1.2 m in width, the project designer should specify the same HMA pay item designation and thickness as used for the mainline. For HMA shoulders greater than or equal to 1.2 m in width, the project designer should specify the HMA pay item designation for the appropriate ESAL level identified in Section 52-13.0

Shoulder corrugations should be in accordance with Section 45-1.02(06).

52-9.02(07) [Section Deleted]

52-9.02(08) HMA Mixture for Approaches

HMA mixture for approaches is a mixture designated for driveways, public road approaches, crossovers, turn lanes, acceleration and deceleration lanes, mailbox approaches on non-paved shoulders, etc. It should be used for short projects where the HMA quantity is less than 200 Mg, i.e., bridge replacement or overlays, small structure replacement, etc., where the paving involves a large amount of handwork or non-paving movement of the paver and rollers.

For driveways, public road approaches and crossovers the limits and HMA section for HMA mixtures for approaches are shown on the INDOT *Standard Drawings*. Where the AADT exceeds the amount shown on the INDOT *Standard Drawings*, the HMA section must be determined in accordance with Section 52-8.0.

For public road approaches the limits for HMA mixtures for approaches may be extended to include up to an additional 30 m of pavement to meet project requirements. If the project requires more than 30 m of additional pavement, the public road approach will be designed and paid for as HMA mixtures for approaches and the additional pavement, will be designed and paid for in accordance with Section 52-8.0.

For HMA turn lanes, HMA acceleration and deceleration lanes, HMA wedges for bridge deck overlay projects, HMA approaches for bridge replacement projects that require less than 200 Mg of HMA material, or HMA pavement less than 60 m in length on small structure replacement projects, the pavement will be designed in accordance with Section 52-8.0 and paid for as HMA mixtures for approaches.

For mailboxes on non-stabilized shoulders HMA mixtures for approaches should be used as specified on the INDOT *Standard Drawings*.

52-9.02(09) Widening with HMA

An existing pavement may be widened up to 1.5 m on each side when widening with HMA; however the minimum width of Widening with HMA specified will be 0.6 m for constructability purposes. This minimum width of widening may result in extra lane width or require some removal of the existing pavement to meet the 0.6 m width. The longitudinal joint of the widened pavements should not be placed in the wheel path of the driving lanes. The pay item designation for this work will be Widening with HMA, regardless of the quantity involved.

If specific project widening requirements exceed 1.5 m, the widened pavement area will not be specified as HMA widening but will be identified as HMA pavement. In this case the pay items specified will be either QC/QA-HMA or HMA in accordance with Section 52-8.0 and the excavation and subgrade treatment will be measured and paid in accordance with the INDOT *Standard Specifications*.

52-9.02(10) Seal Coat

Seal coat is used to seal shoulders, to seal very low volume roadways, and during construction to bond loose material to allow construction traffic to use the surface. The requirements for seal coat are shown in the INDOT *Standard Specifications*.

52-9.02(11) Prime Coat

Prime coat is required for all aggregate and rubblized bases that are to be overlaid. The prime coat binds the top portion of the aggregate with the first HMA layer so that the HMA material will not slide relative to the base material during compaction of the HMA. The requirements for prime coat are shown in the INDOT *Standard Specifications*.

52-9.02(12) Tack Coat

Tack coat is required beneath every course of HMA material that is placed on an existing pavement or newly constructed HMA course. The tack coat binds the new HMA material to the material already in place. HMA or PCCP is to be tacked prior to placement of HMA mixtures. The requirements for tack coat are shown in the INDOT *Standard Specifications.*

52-9.03 PCCP Pavements

The requirements for PCCP are shown in the INDOT *Standard Specifications*. PCCP is constructed on drainable subbase, Subbase for PCCP, or dense subbase, Dense Graded Subbase, on prepared subgrade.

The subgrade should be designed in accordance with the Geotechnical Report. The geotechnical recommendations may include a soil modification or stabilization process, subgrade treatment, or a compacted aggregate stabilization layer.

Subbase for PCCP is placed on the subgrade and is composed of 75 mm of coarse aggregate size No. 8 on 150 mm of compacted aggregate size No. 53. The coarse aggregate size No. 8 is a very permeable layer that collects and removes water entering the pavement subbase system. The compacted aggregate size No. 53 is a dense layer that separates the subgrade from water entering the pavement subbase system. Underdrains shall be included where subbase for PCCP is specified. Dense graded subbase is used under miscellaneous PCCP such as drives, reinforced concrete bridge approaches, etc., or may be used where underdrains are not warranted. Dense graded subbase is composed of 150 mm of compacted aggregate size No. 53.

The designed thickness of PCCP determined by DARWin is placed on the subbase for PCCP. The minimum PCCP thickness is 225 mm. Transverse joints in the concrete pavement are spaced at 5.5 m maximum and are constructed as contraction joints type D-1. The D-1 contraction joints shown in the INDOT *Standard Drawings* have variable size dowel bars dependent on the PCCP thickness. The joint spacing should be modified to meet driveways, inlets, adjacent lanes, etc., such that all joints are continuous across the entire width of pavement including shoulders. These added lengths of D-1 joints should be included in the contract quantities.

Non-standard joints are not to be used in any pavement without approval from the Department's Pavement Steering Committee. If a project designer desires to utilize non-standard pavement joints in an individual contract, a submittal should be made to the Committee through the Materials and Test's Division's Pavement Design Engineer. The pavement designer should contact the Pavement Design Engineer to determine the required submittal contents. The Pavement Steering Committee may require the pavement designer to make a presentation to provide additional justification for the use of non-standard joints.

Quality Control/Quality Assurance (QC/QA) PCCP pay items and PCCP pay items as described in the INDOT *Standard Specifications* are used for projects specifying PCCP. The criteria for using QC/QA-PCCP or PCCP are based on the area of PCC pavement specified. For projects equal to or more than 6000 m^2 of PCCP, the pay item should be QC/QA-PCCP. For projects with less than 6000 m^2 of PCCP, the pay item should be PCCP.

52-9.03(01) PCCP Rehabilitations

PCCP rehabilitations consist of Concrete Pavement Restoration (CPR), preventative maintenance, functional treatment, structural treatment, or undersealing. CPR is used where the existing PCCP is structurally sufficient.

1. Concrete Pavement Restoration. CPR of PCCP pavements may be used as recommended in Section 52-6.03 where the existing PCCP is considered to be structurally sufficient but has reduced serviceability. Typical CPR alternatives are full or partial depth patching, diamond grinding, joint resealing, retrofit joint load transfer, shoulder restoration, slab stabilization (undersealing), longitudinal crack and joint repairs, overlays, or multiple combinations of these alternatives.

   The condition of the driving lane of PCCP is generally a good indicator of the project's suitability for CPR. In addition, FWD testing and core investigation for "D" cracking at joints should be completed. PCCP pavements where cores indicate a "D" cracking distress are not candidates for CPR, functional or PM treatments.

   The limitation of patching for distresses other than "D" cracking for each pavement treatment is based on the full depth patching area required. The limits of the full depth patching for each treatment are listed in Figure 52-9C, PCCP Patching Limits.

2. Preventative Maintenance. A preventative maintenance treatment is specified for rehabilitation of pavements with distresses listed in Section 52-6.03. A preventative maintenance treatment may consist of HMA over concrete, diamond grinding, PCCP patching or joint repairs.

3. Functional Treatment. A functional treatment is specified for rehabilitation of pavements with distresses listed in Section 52-6.03. A functional treatment may consist of HMA over concrete, diamond grinding, PCCP patching or joint repairs.

4. Structural Treatment. A structural treatment is specified for rehabilitation of pavements with distresses listed in Section 52-6.03. A structural treatment may consist of HMA over concrete or PCCP over concrete in accordance with Section 52-9.04. The pavement designer will specify the limits of milling, if required, and the HMA overlay or PCCP thickness. The existing pavement plus the proposed rehabilitation will be designed for structural sufficiency by computing the effective thickness of the existing pavement and comparing this number with the required thickness for the project. The effective thickness for existing PCCP should be determined according to the AASHTO Guide for Design of Pavement Structures, Part III, Chapter 5, Sections 5.6, 5.8, and 5.9 or the Supplement to the Guide.

5. Undersealing. Undersealing consists of a localized activity where a fluid material is pumped under the concrete slab to add support and to fill voids under the pavement. PCCP or asphalt over PCCP composite pavements should be tested with a FWD as described in Section 52-7.03(01) to determine size and limits of voids underlying the pavement.

   FWD testing must be requested well in advance, 4 to 6 months, of the Ready For Letting date, depending on the time of year. See Figure 52-7A for FWD test request procedure and request form.

   FWD testing cannot be performed during the winter months. The District should coordinate traffic control activities for the FWD testing.

The cost of the recommended rehabilitation should be compared to the cost of replacing the existing pavement or an alternate rehabilitation technique using life cycle cost analysis.

52-9.03(02) Curbs and Shoulders

PCCP is constructed with either integral concrete curbs, a widened outside lane with HMA shoulder, or tied full depth concrete shoulders. The integral curbs, widened outside lane, or tied shoulders stiffen the outside edge of pavement to reduce deflections. D-1 joints are required across the entire PCCP. Compacted aggregate or geotextile should be specified alongside PCCP curbs or shoulders to prevent erodible material from infiltrating the underdrain system. The typical sections for PCCP shoulders are included in Section 52-13.0.

52-9.03(03) Reinforced Concrete Bridge Approach

The requirements for Reinforced Concrete Bridge Approach (RCBA) are shown in the INDOT *Standard Specifications*. RCBA is constructed on dense graded subbase on prepared subgrade.

A RCBA is used at bridges to transition from PCC or HMA pavement to the bridge deck / mudwall. For PCCP, the RCBA spans from the sleeper slab to the pavement ledge on the mudwall. For HMA pavements, the RCBA spans from the end of the HMA pavement to the pavement ledge on the mudwall. The RCBA is reinforced to account for unsupported conditions due to settlement at end bents or abutments. The RCBA and reinforcing steel details are shown on the INDOT *Standard Drawings.*

52-9.04 Composite Pavements

The design elements of composite pavements will be determined based on the scope of the project determined from Section 52-7.0.

52-9.04(01) New Construction

HMA over aggregate composite pavement will be designed as flexible pavement in accordance with Section 52-8.0 and is limited to projects with less than 1 million ESALs. See Figure 52-13E in the Typical Sections for specific design details.

The project designer should use the appropriate mixture designations shown for QC/QA-HMA or HMA mixtures in accordance with Section 52-9.02. The compacted aggregate shall be as designed within the limits shown in the Typical Sections.

52-9.04(02) Rehabilitation

HMA over asphalt/PCC composite pavement will be designed to match the existing pavement. If widening of the pavement is needed and the existing subbase is open graded, the widened PCC base will utilize Subbase for PCCP. If the existing subbase is dense graded, the widened PCC base will utilize Dense Graded Subbase. The minimum width of PCC base widening is limited to pavement widening less than or equal to 1.5 m. An existing pavement may be widened up to 1.5 m on both sides with PCC Base. The pay item designation of this work will be Widening with PCC Base in accordance with the INDOT *Standard Specifications*. For constructability purposes widening should be a minimum of 0.6 m. The longitudinal joint of the widened PCC Base should not be placed in the wheel path of the driving lanes.

If the existing pavement has open graded subbase with underdrains, the existing longitudinal underdrain system will be perpetuated with additional outlets added in accordance with Section 52-10.0. If the existing pavement has dense graded subbase, underdrains will not be added.

The existing asphalt/PCC composite pavement should be milled not less than 25 mm in accordance with Section 52-7.05 and prepared in accordance with the INDOT *Standard Specifications*.

52-10.0 UNDERDRAINS

Underdrains are perforated pipes and coarse aggregates usually installed longitudinally in the vicinity of pavement edges. The purpose of an underdrain is to remove water from the subgrade and the pavement structure.

52-10.01 Definitions

Aggregate for Underdrains. Coarse aggregate size No. 8 or 9 used to backfill an underdrain pipe trench.

Dual Access Underdrain. A run of underdrain that features outlet pipes connected to both ends of the underdrain pipe. The dual access outlet pipes are installed to provide access to the underdrain pipe for inspection and maintenance purposes.

Geotextile for Underdrains. An engineered geotextile fabric used to prevent soil particles from contaminating an underdrain pipe and aggregate for underdrains.

HMA for Underdrains. An open graded HMA used to patch existing asphalt shoulders over a retrofitted underdrain pipe or an outlet pipe.

Intercept Elevation. The invert elevation at the connection between an underdrain pipe and a PVC connection at drainage structures or outlet pipe.

Intercept Station. The station at which the connection between an underdrain pipe and a PVC connection at drainage structures or outlet pipe occurs.

Obstacle. A project feature, such as a paving exception, bridge, culvert, etc., that prevents the continuous installation of underdrain pipe.

Outlet Elevation. The invert elevation of an outlet pipe or PVC pipe connection where the collected water leaves the outlet pipe.

Outlet Pipe. A non-perforated pipe that conveys water collected by the underdrain pipe to a side ditch, median ditch, or drainage structure. An outlet pipe may also be installed at the high end of an underdrain pipe to create a dual access underdrain.

Outlet Protector. A concrete slab constructed on a sideslope to protect outlet pipe ends.

Outlet Station. The station where an outlet pipe discharges to the sideslope or is connected to a drainage structure.

Retrofitted Underdrain. An underdrain pipe installed along an existing pavement edge in conjunction with a pavement rehabilitation operation, such as rubblization, cracking and seating, or overlaying.

Single-Access Underdrain. A run of underdrain that features an outlet pipe connected to the low end of the underdrain pipe only.

Special Underdrain. An underdrain pipe installed at a specified slope that is not parallel to the pavement profile, resulting in an installation that varies in depth along its length.

Tangent Grade. The specified grade between two adjacent points of vertical inflection (PVIs) on the vertical alignment of the proposed pavement.

Underdrain Pipe. A perforated pipe installed at the bottom of a longitudinal underdrain trench.

Underdrain Run. An individual segment of underdrain pipe and its associated outlet pipe or pipes.

Underdrain System. The system that collects water from the subgrade and pavement structure and conveys it to the drainage system. Typical underdrain system elements include the underdrain trench, underdrain pipe, aggregate for underdrains, geotextile for underdrains, outlet pipe, etc.

Video Inspection. The process of inspecting individual underdrain runs after installation using a video camera.

52-10.02 Existing Underdrain Perpetuation

Roadways with existing underdrains should have all outlet pipes perpetuated as part of any project. The project designer should note if existing underdrains are present on a project and locate all existing outlet pipes to evaluate them for any needed maintenance or repair. Any required repair or maintenance, such as unearthing and replacing an outlet pipe or reconstructing an outlet protector should be included in a proposed project.

52-10.03 Underdrain Warrants

Underdrains are required for all projects, including LPA projects, that meet either of the following conditions.

1. Projects with a design year Average Annual Daily Truck Traffic (ADTT) volume of 100 per day or greater, and a net paving length of 1000 m or greater.

2. Projects where both pavement sections adjacent to the project area have existing underdrains.

Underdrains are also required where using subbase for PCCP, HMA class OG mixtures, and where an existing PCCP is to be cracked and seated or rubblized.

Underdrains are not generally utilized on preventative maintenance or functional treatment projects, as defined in Sections 52-7.04(01) and 52-7.04(02), respectively.

52-10.04 Design Criteria

52-10.04(01) Slope

1. Underdrain Pipe. At locations where the tangent grade is 0.2% or steeper, the underdrain pipe will be installed at a fixed depth below the pavement. Where the tangent grade is flatter than 0.2%, special underdrains are required. The special underdrain slope should be 0.2 percent or steeper.

2. Outlet Pipe. The minimum outlet pipe slope is 0.3%.

52-10.04(02) Size

1. Underdrain Pipe. Projects that include construction of new pavement require 150 mm diameter underdrain pipe. Projects that rehabilitate existing pavement require 100 mm diameter underdrain pipe.

2. Outlet Pipe. All projects require 150 mm diameter outlet pipe. For projects that require 100 mm underdrain pipe, outlet pipe fittings will be utilized to increase the outlet pipe size to 150 mm.

52-10.04(03) Outlet Spacing

Outlet pipes are required at all low points of sag vertical curves. They are also required at other low points encountered along the vertical alignment of a project, such as the project beginning and ending points and obstacle locations.

Additional outlet pipes are likely to be required throughout the project limits. The maximum underdrain pipe length should not exceed 200 m. If the proposed underdrain pipe length is greater than 120 m, a dual access underdrain is required. If the outlet spacing results in an underdrain pipe length that is 120 m or less, a single access underdrain may be utilized.

52-10.04(04) Location

Underdrains, where warranted in accordance with Section 52-10.03, should be constructed along all pavement edges. The underdrains should be continuous through all intersections, ramps, turn lanes, tapers, etc., and should be located in the pavement section as shown in Section 52-13.0. For approaches where underdrains are warranted in accordance with Section 52-10.03, the underdrains should extend from the mainline underdrain to the limit of the new approach pavement.

1. Underdrain Pipe. The underdrain pipe location within each proposed cross section should be in accordance with Section 52-13.0.

   If an inlet, catch basin, manhole, or similar structure is located along the normal alignment of an underdrain pipe, the underdrain pipe may be connected directly to the drainage structure. The connection should be at least 150 mm above the structure invert elevation.

Direct connections of an underdrain pipe to a pipe culvert or a precast concrete culvert should be avoided.

2. Outlet Pipe. The connection between an outlet pipe and an underdrain pipe should be as shown on the INDOT *Standard Drawings*. Ninety degree elbows or tees should not be utilized in these connections.

   As shown on the standard connection detail, one of the 45° elbows may be omitted if necessary to provide a satisfactory outlet.

   Separate outlet pipes should be provided for each underdrain pipe. Outlet pipes for adjacent underdrain pipes at sag vertical curve low points or for adjacent dual access underdrains should be installed in a common trench as shown on the INDOT *Standard Drawings*. Outlet pipes installed in a common trench should outlet at the same elevation.

   The outlet elevation should be at least 600 mm above the flow line elevation of a side ditch, 300 mm above the flow line elevation of a median ditch, or 150 mm above the invert elevation of an inlet, catch basin, manhole, or similar structure.

   If an underdrain pipe has no suitable outlet available at an adjacent ditch line or drainage structure, the outlet pipe may be installed under the pavement to an acceptable outlet on the opposite side of the roadway. In these situations, the outlet pipe installation should be designed so as not to conflict with the underdrain pipe installation along the opposite pavement edge.

52-10.04(05) Backfill

1. Underdrain Pipe. Aggregate for underdrains is used to backfill underdrain pipe trenches. In addition, retrofitted underdrains require HMA for underdrains for patching existing asphalt shoulders above the underdrain pipe trench as shown on the INDOT *Standard Drawings*.

2. Outlet Pipe. Outlet pipe backfill includes structure backfill and suitable material placed as shown on the INDOT *Standard Drawings.* HMA for underdrains is required for patching existing asphalt shoulders above the outlet pipe trench associated with a retrofitted underdrain as shown on the INDOT *Standard Drawings*.

52-10.04(06) Outlet Protectors

Outlet protectors are required at all locations where an outlet pipe intersects a median or side slope. An outlet protector may contain two outlet pipes.

There are three outlet protector types available. The INDOT *Standard Drawings* include details for each protector type.

Figure 52-10A, Outlet Protector Slope Limits, includes acceptable slopes for construction of the three outlet protector types.

The outlet protector selected should be the largest protector appropriate for the proposed slope that can be constructed considering all conflicts to the outlet location.

52-10.04(07) Geotextile for Underdrains

There are two applications where geotextiles are used in conjunction with underdrain pipe installation. The first application is as an underdrain pipe trench liner. Trench lining should only be used if the geotechnical report recommends such an installation or if it can be verified by other means that silt or loam soils exist within the project limits. The second application for geotextile is to prevent the contamination of the underdrain pipe backfill during the construction of embankment behind a concrete curb. Installation of the geotextile should be in accordance with Section 52-13.0, and is required in conjunction with all curb construction above an underdrain pipe.

52-10.04(08) Video Inspection

Video inspection of underdrain systems should be included in all projects with at least 1000 m of underdrain pipe. The contract quantity should be as shown in Figure 52-10B, Video Inspection Pay Quantities.

52-10.05 Contract Document Preparation

52-10.05(01) Plans

Information related to underdrains should be shown on the following sheets.

1. <u>Typical Cross Section Sheet</u>.

    a. The underdrain pipe location as illustrated in Section 52-13.0
    b. Underdrain pipe trench and backfill details

2. <u>Plan and Profile Sheet</u>. Special underdrain limits should be shown on the profile portion of the sheet.

3. <u>Detail Sheets</u>. All project-specific details should be shown on these sheets.

4. <u>Underdrain Table</u>.

    a. Underdrain Pipe.
        (1) Beginning and ending stations
        (2) Flow line elevations at beginning and ending stations
        (3) Pipe size
        (4) Special underdrain grade, if applicable
        (5) Pipe quantity
        (6) Aggregate for underdrains quantity
        (7) HMA for underdrains quantity
        (8) Geotextile for underdrains quantity

    b. Outlet Pipe.
        (1) Outlet station
        (2) Outlet elevation
        (3) Intercept station
        (4) Intercept elevation
        (5) Outlet protector or structure number at outfall
        (6) Outlet ditch or drainage structure invert elevation at outfall
        (7) Pipe quantity
        (8) Structure backfill quantity
        (9) HMA for underdrains quantity

    c. Outlet Protectors.
        (1) Outlet protector type
        (2) Outlet protector location
        (3) Outlet protector quantity

52-10.05(02) Specifications

Requirements for underdrains are shown in the INDOT *Standard Specifications.*

52-10.05(03) Standard Drawings

Details for underdrains and outlet protectors are shown on the INDOT *Standard Drawings*.

52-10.05(04) Pay Items

The project designer should determine the contract quantities for the appropriate pay items associated with the underdrain construction. The pay items include Pipe, Type 4, Circular, ___ mm; Pipe, Underdrain Outlet, 150 mm; Aggregate for Underdrains; Structure Backfill; HMA for Underdrains; Geotextile for Underdrains; Outlet Protector, ___; and Video Inspection.

52-11.0 PREVENTATIVE MAINTENANCE

Preventative Maintenance (PM) is a pavement surface treatment used to preserve and extend the service life of pavements. PM projects are intended to arrest light deterioration, retard progressive damage and reduce the need for routine maintenance. The proper time for PM is before the pavement experiences severe distress, structural problems, and moisture or aging related damage. These activities can be cyclical in nature and may correct minor deficiencies as a secondary benefit. PM projects should improve high stress areas or localized problems.

Preventative Maintenance treatments are typically not used where the scope of work is to correct pavement cross slopes, horizontal alignments, vertical alignments, superelevation problems, placement of turn lanes or auxiliary lanes, improvement of public approaches or drives, or guardrail adjustments or repair. PM projects may include various incidental enhancements or combinations at isolated locations in accordance with Chapter Fifty-six.

The most commonly used PM treatments are as follows:

1. Chip Sealing. Chip sealing is the full width treatment of the surface with hot asphalt material and coarse aggregate to prevent deterioration of the surface. It provides waterproofing, low severity crack sealing, and improved friction. Sections should show no structural deficiencies prior to chip sealing. For PM, the seal coat should be placed at a time before cracks become braided, depressed, or any patching is needed. A previously

chip sealed surface may be chip sealed a second time. Criteria for selecting sections for chip sealing are as follows:

a. AADT < 2000 (higher volume, if traffic can be controlled);
b. on alligator cracking;
c. Pavement Condition Rating (PCR) between 80 and 90 with only moderate cracking;
d. roughness (PSI) > 3.0;
e. rutting < 6 mm; and
f. typical surface age of 5 to 8 years.

2. Crack Sealing. Crack sealing is the cleaning and sealing of open cracks or joints in asphalt pavement and shoulders to prevent the entry of moisture and debris. Cracks or joints should be cleaned out and sealed on a 1- to 3-year cycle. Cleaning may be accomplished by sawing or routing. This work should be scheduled in the cooler months when the pavement has contracted and the cracks or joints have widened.

3. Microsurfacing. Microsurfacing is a thin polymer-modified asphalt emulsion mixture. Microsurfacing may be used for the texturing, sealing and filling of ruts. Existing pavements should have no large cracks or excessive irregularities such as shoving. Cores should be taken to determine the void content of the existing pavement layers in order to determine the stability and permeability of the existing pavement. The cost of microsurfacing should be compared to a conventional 90 kg/m^2 thin HMA inlay and its required milling. An overlay should be used based on its structural value unless the microsurfacing is more economical. Core data and cost data should be reviewed with the Materials and Tests Division's Asphalt Engineer for specific recommendations.

4. HMA Inlay. Thin HMA inlays, or milling and filling, consist of milling the existing surface and replacing it with a new asphalt surface to the original surface elevation. For PM, the surface condition may have minor defects but should not have significant potholes, depressed cracks, or major distresses. Correct timing of the treatment is critical to its longevity. Criteria to be used when considering thin HMA inlays are as follows:

a. corrugations or washboarding in the surface course;
b. Pavement Condition Rating (PCR) 75 to 85 with no structural defects;
c. roughness (PSI) 2.5 to 3.5;
d. rutting > 13 mm ;
e. surface friction improvement; and
f. typical surface age of 7 to 10 years.

5. HMA Overlay. A single course 90 kg/m^2 HMA overlay may be used as a PM treatment if applied in a timely manner. This application may be used to preserve rideability or

correct minor surface problems. Criteria to be used when considering thin HMA overlays are as follows:

a. extensive raveling or weathering of the surface;
b. pavement Condition Rating (PCR) 75 to 85 with only moderate cracking;
c. PM on a lower volume road over existing successive chip seals to restore rideability;
d. roughness (PSI) < 3.0; and
e. rutting < 13 mm.

6. Sand Sealing. Sand sealing is a continuous full width sealing of the surface with hot asphalt material and fine aggregate to prevent deterioration. It provides waterproofing, low severity crack sealing, and improvement of the surface by mitigating the effects of aging. The criteria for the use of sand sealing are similar to those for chip sealing. However, a surface being sand sealed may have more low-severity cracks. Sand sealing may be more cost effective than crack sealing when extensive amounts of tight fine cracks require manual sealing. Sand sealing should not be placed on existing sand surfaces.

7. Asphalt Sawing and Sealing Joints. Sawing and sealing maintains neat line reflective cracks or construction joints where a planned crack can be formed by sawing to provide a reservoir for the sealant. This technique is used for sealing cracks on newer HMA surfaces where single relatively straight joints or reflective cracks have developed. This PM treatment may be periodic once more cracks develop as the pavement ages, but typically it is performed within the first four years of the surface life.

8. PCCP Sawing and Sealing Joints. Contraction joints and longitudinal joints on concrete pavement should be inspected periodically and cleaned and resealed as required. For PM, timely sealing of the joints prevents dirt and moisture from entering the joints. Rigid pavement, 8 to 10 years old, should be inspected. If, on inspection, 10% of the joints have loose, missing, or depressed sealant, sawing and sealing of the joints should be considered. The joints should be sawed to remove any old sealant and cleaned to reshape the joint seal reservoir.

9. Retrofit Joint Load Transfer. Retrofit joint load transfer consists of the retrofitting of dowels in jointed PCCP to re-establish load transfer across the contraction joints or random cracks. The pavement performance is improved by means of reducing pumping, corner breaks, or faulting. This work consists of the cutting of slots, placing new dowels or reinforcing bars therein, then cementing them into place. Life-cycle cost analysis should be applied to check for the cost-effectiveness of this PM treatment.

10. <u>Diamond Grinding</u>. Diamond Grinding is a procedure used to restore or improve pavement rideability by removing surface defects that develop based on traffic loading and environmental conditions. As traffic, primarily trucks, uses the roadway and encounters deteriorated joints or other surface defects, they begin to bounce vertically resulting in accelerated dynamic loading of the pavement. The increased loading in the pavement consequently increases the rate of deterioration and further reduces the serviceability, increases user costs, and increases maintenance costs. Diamond grinding enhances surface friction of an existing pavement surface. The resulting corduroy-like surface provides ample channels for water to escape the surface resulting in reduced hydroplaning potential. Diamond grinding is recommended to restore rideability when faulting exceeds 13 mm for 20% of the joints, and the pavement terminal/serviceability index (PSI) does not drop below 3.5.

11. <u>Drainage Inspection and Cleaning</u>. Drainage inspection and cleaning consists of the inspection of drainage structures, e.g., underdrain outlets, ditches, catch basins, inlets, and the cleaning of these structures to maintain or restore the flow of water. The location of underdrains should be identified and the outlets periodically cleaned. The INDOT *Maintenance Management Field Operations Handbook* provides for drainage inspection and cleaning details.

52-12.0 LIFE-CYCLE COSTS

<u>52-12.01 General Discussion</u>

The material presented in this section represents the methodology to perform a Life-Cycle Cost Analysis (LCCA) for pavement projects. It is not all-inclusive, and several resources are available for further explanation of the subject, such as the FHWA's SA-98-079, *Life-Cycle Cost Analysis in Pavement Designs*.

Life-Cycle Cost Analysis is an economic evaluation technique that builds on the principles of economic analysis to evaluate the overall long-term solutions for all types of projects. LCCA considers initial and future agency, user, and other relevant costs over the life of various alternatives discounted to provide comparative costs. This technique allows a project's cost to be compared over a specified time period. The selection of design alternatives should be made based on a LCCA sensitivity analysis for pavement life costs. The Department recommends a LCCA be completed on any project which includes several feasible alternatives.

In the simplest situation, a LCCA evaluates costs associated with two or more particular strategies or design scenarios over an analysis period including the initial construction and at least one succeeding rehabilitation activity. These costs for the alternate scenarios or money flows are discounted to the present time. A comparison of the net present value of the scenarios is made to provide information regarding just one of the factors involved in the selection of pavement designs.

The economic evaluation of two feasible design strategies or design scenarios has no relation to the method of financing, or the total cost of the project. Inflation is not a factor in the evaluation since two or more scenarios' cash flows are being compared over the same time period with presumably the same inflation effects. It is better to use "constant real dollars" in the LCCA and then let the budget analysis decide funding sources, inflation rate, and cash flow requirements.

One of the common terms for this method of analysis is the Equivalent Uniform Annual Cost (EUAC) method. It incorporates the initial capital costs and adds the value of future cash flows into equal annual payments over the analysis period. This analysis technique does not determine if a project may be economically feasible. Any two scenarios being evaluated with a total net present value within 10% are considered to be essentially the same. Other factors should be used to make the final selection such as initial costs, constructability, work zone traffic control, user delay costs, etc.

52-12.02 Definitions

Analysis Period. The analysis period is the number of years over which the pavement analysis is conducted. The analysis period should include the initial pavement cost and the cost for at least one subsequent rehabilitation. The analysis period should be 40 years.

Discount Rate. The discount rate is used to equate the cash flows to present worth and determine EUAC. For general purposes, a 4% discount rate can be assumed. However, it is recommended that a range of rates from 0% to 10% be used to determine if the alternate scenarios are discount-rate sensitive. The results of the sensitivity analysis should be shown.

Equivalent Uniform Annual Cost (EUAC). The EUAC is the combining of initial capital costs and all future expenses into equal annual payments over the analysis period. The equation uses the Capital Recovery Factor and is shown below.

$$EUAC = (PW)\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right]$$

Where: PW = present worth
i = discount rate
n = number of years from year zero

LCCA Design Life. LCCA design life is the estimated service life of the pavement. For LCCA purposes only, the design lives shown in Figure 52-12C, LCCA Pavement Design Lives, should be used for the various initial, maintenance, or rehabilitation options.

The estimated design life may be varied based on engineering judgment of the existing conditions, past performance, or the condition of the drainage system. The design life of the pavement should be varied to test the LCCA for sensitivity. The design lives used for the sensitivity analysis should be documented.

The Materials and Tests Division's Pavement Design Engineer will maintain a listing of the costs for various maintenance or rehabilitation options identified as part of the proposed LCCA. The pavement designer should utilize these costs to compare life cycle costs of different pavement treatments.

Life-Cycle Cost. The life-cycle cost is the total of the costs associated with a pavement over a set period of time. The costs include the initial capital cost of construction, future maintenance, and future rehabilitation. The life cycle cost may also include user delay costs during construction and maintenance, user vehicle operating and accident expenses, engineering fees, or any other expenditures over the life of the pavement. It will also include the residual value, or salvage value of the pavement, at the end of the time period. The initial construction cost and subsequent maintenance and rehabilitation costs are the most reliable costs to use. The pavement designer should use the performance years of the rehabilitation alternatives over the life of the pavement.

The cost of work zone traffic control and the cost of user delays during construction between various designs may have a significant effect on the analysis. These costs should be quantified for the various designs.

Typical LCCA costs include the following:

1. initial construction;
2. subsequent maintenance or rehabilitation options;
3. salvage value;
4. work zone traffic controls;
5. traffic delay and queue time;
6. detours;
7. cccelerated construction costs, A+B bidding;
8. complications of interchanges, bridges or phasing; and
9. benefits as a negative cost where alternatives have quantifiable amounts and can be treated equally.

Present Worth (PW). The PW value of money at year zero of future expenditures. The future cash flow is discounted by the discount rate to determine PW. The equation for the present worth of a future outlay is as follows:

$$PW = F\left[\frac{1}{(1+i)^n}\right]$$

Where: F = future construction cost
i = discount rate
n = number of years from year zero

Salvage Value (SV). Salvage value is the residual value of the pavement's remaining service life at the end of the analysis period. As an example, if the pavement surface has five years of remaining life at the end of the analysis, the pavement has a remaining value which has not been used. The Department defines SV as the construction cost of the last cycle times the ratio of the remaining service years to the last cycle design life. The SV of the pavement is calculated by the following equation.

$$SV = (\$)\left(\frac{RL}{DL}\right)$$

Where: $ = last cycle construction cost
RL = remaining service life in years
DL = last cycle design life in years

52-12.03 Analysis Steps

1. Determine the feasible alternatives for construction, subsequent maintenance, and rehabilitation options. The design life of each action should be determined. The alternatives and their application time will aid in determining the total analysis period for LCCA. The design life should include at least one subsequent rehabilitation, therefore, the analysis period may not be the same for all projects. However, each alternative should have the same analysis period.

   A graphic activity time line for each alternative is a useful tool to show the different scenarios over the analysis period as shown in Figure 52-12A, Activity Time Example with Cash Flow.

2. Calculate the costs of the alternatives and subsequent maintenance and rehabilitation options using only those costs unique to each alternative. Like costs in each alternative

will result in a net zero difference and should be neglected. For example, if two alternatives have similar traffic control, these costs need not be calculated, since a $100,000 crossover in each is a net zero difference in present worth. Costs of future rehabilitations should be calculated using present day dollars. The net cost of each action may be displayed on the graphic activity time line to show the cash flow.

3. Calculate the present worth based on the time and future cost for each net expenditure. A range of discount rates is recommended to determine the sensitivity between different alternatives. For example, if alternate A at 2% discount and 8% discount is less expensive than alternate B at the same rates, then the discount rate does not change the outcome.

4. Calculate the total present worth and EUAC for each alternative. The PW costs and EUACs may be compared to rank the alternatives. A graph of the EUAC for each alternative at the various interest rates is useful to show the different rates. For example, see Figure 52-12B, Annual Cost Comparison, Life Cycle Resurface Alt. 1 & 2.

5. Complete the LCCA documentation by listing time of treatments, cost estimate, PW, EUAC, and discount rate sensitivity.

52-13.0 TYPICAL PAVEMENT SECTIONS

52-13.01 HMA Pavements

Typical HMA mainline pavement sections are shown in Figures 52-13A through 52-13E.

52-13.02 PCC Pavements

Typical PCC mainline pavement sections and Joints locations are shown in Figures 52-13F through 52-13H. Joints locations are shown in Figure 52-13R.

52-13.03 Miscellaneous Pavement Sections and Details

Overlay sections for Interstate-route or multi-lane pavements are shown in Figures 52-13 I and 52-13J.

Underdrain details are shown in Figures 52-13K through 52-13Q.

Ramp sections are shown in Figures 52-13S through 52-13U.

Concrete curb sections are shown in Figures 52-13V and 52-13W.

Parking lot sections are shown in Figure 52-13X.

52-14.0 PAVEMENT DESIGN REQUESTS AND INSTRUCTIONS

Pavement design requests should be submitted on the appropriate forms to the appropriate pavement designer as described in Section 52-2.0. Instructions for completing the forms are shown in Section 52-14.03.

52-14.01 Pavement Design Request for INDOT Project

A Pavement Design Request instructional form for an INDOT project is shown as Figure 52-14A.

52-14.02 Pavement Design Request for Local Public Agency Project

A Pavement Design Request instructional form for an LPA project is shown as Figure 52-14B.

52-14.03 Instructions For Completing Pavement Design Request Forms

(1) For INDOT project, I, US, or SR and number. For LPA project, CR and number, or name of road.

(2) For INDOT project, County number is that in alphabetical listing. For LPA project, name of county, city, or town making request.

(3) Design identification number.

(4) Net length of project in urban/rural areas.

(5) Descriptive location of project limits including reference markers. The discussion should include the proposed scope of the project as it is related to the pavement and its general classification, i.e., preventative maintenance, functional or structural overlays, reconstruction, widening, added travel lanes, etc. Milling, steep grades?

(6) Descriptive listing of the history of the pavement, year of construction and subsequent overlays. If the project is a Partial 3R or rehabilitation type project, then core depth reports, FWD report, and color pictures are to be submitted.

(7) The type of the existing pavement, i.e., aggregate, asphalt, PCCP, or composite pavement, shall be identified along with the width and thickness of the existing pavement.

(8) Identify the width, thickness, and condition of the existing shoulders/curbs.

(9) Does the existing pavement have underdrains?

(10) Identification of adjacent pavement types.

(11) The proposed posted speed limit for the project.

(12) Number of stopped conditions, i.e., stop signs, traffic signals, intersections, etc.

(13) List the number and width of the travel lanes and turn lanes to be paved.

(14) Describe the type and width of shoulders or curbs planned for the project.

(15) Provide the appropriate CBR or Resilient Modulus for HMA, "k" modulus of subgrade reaction value for PCCP, the type of Subgrade treatment, and any other special geotechnical recommendations like peat areas or other settlement areas should be identified.

(16) The year the project is to be constructed.

(17) Construction year AADT.

(18) Future year the project is to be designed for.

(19) The design year projected AADT.

(20) Percent trucks of the AADT that are Class 5 or higher.

(21) Identify the desired pavement type and the engineering reason for the selection.

(22) For INDOT projects, name of pavement designer or consultant.

(23) If Yes, attached completed document.

(24) Complete proposed pavement and shoulder description, including pay items, and amounts of each layer, for either QC/QA HMA, HMA or QC/QA PCCP, or PCCP Included as applicable, milling and the depth of milling, subgrade treatment type, widening, Subbase for PCCP, underdrains, etc.

(25) Signature of Professional Engineer submitting pavement design request.

(26) Seal of Professional Engineer submitting the pavement design request.